WILLIAMS

Design of a Steel Grand-Stand

Civil Engineering

B. S.

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DESIGN OF A STEEL GRAND-STAND

BY

ROY CAMPBELL WILLIAMS

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

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I recommend that the thesis prepared under my supervision by ROY CAMPBELL WILLIAMS entitled Design of a Steel Grand-Stand be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

C. W. Malcolm

Asst. Professor of Structural Eng'g.

Recommendation approved

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Head of Department of
Civil Engineering.

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DESIGN OF A STEEL GRAND-STAND.

INTRODUCTION.

Within the last few years there has been a great increase in the construction of large steel and reinforced-concrete grand-stands and a corresponding decrease in the construction of wooden ones. The first large steel grand-stand was erected at Monmouth, New Jersey. It is 700 ft. long, 310 ft. wide, and has a seating capacity of 10,000 people. The roof is of the cantilever type, extending 75 ft. to the front and 35 ft. to the rear. Another stand of large capacity was built at Yonkers, New York, for the Empire City Trotting Club. It is 400 ft. long, 30.5 ft. wide, and 70 ft. high, and has a cantilever roof extending 25.5 ft. to the front and 15.5 ft. to the rear. The entire cost of the structure was $100,000, and its seating capacity is 7,700. Both the Pittsburg National League and the Chicago American League Base Ball Clubs have recently erected steel grand-stands with capacities of approximately 30,000 people. This great change in the construction of grand-stands is mainly due to three facts: (1) the great increase in the price of lumber, (2) the fact that wooden grand-stands are not fireproof, and (3) that they are unsafe for the great crowds which attend the athletic contests of the present time. The question as to the desirability of building a steel or a reinforced-concrete grand-stand depends to a considerable extent upon its location. If cement and crushed stone are easily obtainable and steel is very expensive to ship in, the reinforced-concrete grand-stand would probably be the one chosen. If local conditions are such that steel and materials for concrete can be obtained with approximately equal transportation charges the steel grand-stand is often chosen, because: (1) it is easier to construct, (2) it is easier to inspect, both during and after construction,

and (3) it is usually cheaper. As this grand-stand is designed for a football field in Chicago, the framework will be built of steel.

GENERAL FEATURES OF THIS DESIGN.

The grand-stand which is designed in this thesis is 303 ft. long, 55 ft. wide, and 45 ft. 6 in. high (see Plate I). The lower deck has a seating capacity of 4000 people and is divided into 9 sections, each 33 ft. in length. Each section has 22 rows of seats, and each row is capable of seating 20 people. The aisles are all 3 ft. wide and terminate in a concrete walk 12 ft. wide which runs along the front of the structure. The tiers of seats are supported on 10" I's25#, spaced 16 ft. 6 in. apart, these in turn being supported by columns spaced 11 ft. apart. The bases of the columns rest upon concrete footings which vary in size from $2\frac{1}{2}$ ft. square to $5\frac{1}{2}$ ft. square, depending upon the load which they support (see Plate II). The front columns are built of Z-bars and plates, while the rear columns are composed of angles and plates. The intermediate columns are made of latticed channels, which give a more economical section for these columns.

The upper deck has a seating capacity of 2,000 (see Plate I). Like the lower deck it is divided into 9 sections, each 33 ft. wide. It has 3 ft. aisles, but has only 11 rows of seats. It is supported by transverse trusses spaced 16 ft. 6 in. apart. Every third truss is a through truss (see Plate IV), supported both in the front and rear by columns, while the two intermediate trusses (see Plate V) are supported at the rear by columns and in front and at the center by longitudinal trusses, which connect with the through trusses (see Plate IV). In this way a minimum number of columns is used, and, as the front 11 ft. of the upper deck is cantilevered and the lower chord extends upward at an angle of about 12 degrees, the view

is practically unobstructed. Exit from the upper deck is obtained by a 5 ft. 6 in. cinder-concrete walk which runs along the apex of the truss and connects at both ends with stairways which lead to the ground. The rear part of the upper deck is covered by a tar and gravel roof, supported by 2 by 4-in. rafters on 7"['s 9.75# purlins. See Plate II.

LOADS AND STRESSES.

The stresses (see Tables I and II) in the transverse trusses were solved graphically (see Plate III), while those in the longitudinal trusses, seat beams, columns, etc., were found algebraically. To find the stresses due to wind on the upper deck it was assumed that the horizontal component of the wind was carried down the knee-brace to the seat-beam and thence down into the footings. The rear of the lower deck is to be boarded up. The wind is all taken as horizontal and is assumed to travel down the seat-beam into the front footings. Thus the front column can be designed for direct load only. Assuming that the trusses would weigh 5 lb. per sq. ft. and computing the weight of the other materials, it was found that the dead load under the seats would be about 50 lbs. and elsewhere about 20 lbs. per sq. ft. It was assumed that the average person weighed 150 lbs. and as 4 sq. ft. were allowed to each person, the live load was found to be 37.5 lbs. per sq. ft. One hundred per cent was allowed for impact so that the live load used was 75 lbs. per sq. ft. The wind pressure on a vertical surface was taken at 30 lbs. per sq. ft., and the normal values were figured from the straight line formula, $P_n = \frac{P}{45}A$.

SPECIFICATIONS USED.

The design was governed by Ostrup's specification, of which the following are extracts:

(a)

Axial tension in main members, net section, 16000 lbs. per sq. in.

(b)

Extreme fiber stress due to bending, for rolled shapes, built sections,

and plate girders, 16000 lbs. per sq. in.

(c)

Axial compression in main members, gross section, $S = 16000-70\frac{l}{r}$.

(d)

Shear on field rivets, 8000 lbs. per sq.in.

Shear on shop rivets, 10000 lbs. per sq.in.

(e)

Bearing of field rivets, 16000 lbs. per sq. in.

Bearing of shop rivets, 20000 lbs. per sq. in.

(f)

Allowable pressure on ordinary earth, $1\frac{1}{2}$ tons per sq. ft.

Allowable pressure on tamped or naturally solid earth, 3 tons per sq. ft.

Minimum size of angle, $2\frac{1}{2}\times 2\times\frac{1}{4}$-in.

No rivets, except in beam connections and lacing bars, shall be less than $\frac{3}{4}$-inch.

Estimated Cost.

The estimated cost of the grand-stand designed in this thesis is as follows:

617800	lbs. of steel at $3\frac{3}{4}$ cents per lb.	=	\$23167.50
215	cu. yds. of slag-concrete at \$9.00 per cu. yd.	=	1935.00
57	cu. yds. of footing-concrete at \$5.00 per cu. yd.	=	285.00
97	squares of roofing at \$4.00 per square	=	388.00
2240	ft. of $1\frac{1}{2}$ in. gas-pipe @5.5 cts. per ft.	=	123.20
48000	board ft. of lumber at \$45 (laid) per M	=	2160.00
	Total	=	\$28068.70

TABLE 1.

Stresses-Truss "A".

Member	Dead Load	Wind Right	Wind Left	Live Load	Maximum	Minimum
x-1	-21700	+6660	-24300	-8800	-54800	-15040
x-2	-21700	+6660	-25300	-8800	-55800	-15040
x-4	-19900	+ 570	-17800	-8800	-46500	-14200
x-6	-18100	-1500	-13300	-8800	-40200	-18100
x-8	-16150	-2580	-11500	-8800	-36950	-16150
x-11	- 8350	-2730	- 5150	-5500	-19500	- 8350
x-13	- 5500	-2300	- 3850	-2450	-11800	- 5500
x-15	+ 6100	+ 120	0	+9350	+15570	+ 6100
x-17	+ 2950	- 300	0	+4700	+7650	+ 2650
x-18	+ 3000	+1120	0	+4700	+8820	+ 3000
a-1	+18750	-5700	+20300	+7100	+46150	+13050
y-3	+17250	-5880	+17550	+7100	+41900	+11370
y-5	+15650	-3600	+13500	+7100	+36250	+12050
y-7	+14050	-2700	+10400	+7100	+31550	+11350
y-9	+12450	-2180	+7700	+7100	+27250	+10270
y-10	+12450	-2180	+7700	+7100	+27250	+10270
y-12	+8800	-2140	+5140	+5500	+19440	+6660
y-14	+4700	-1900	+3250	+2000	+ 9950	+ 2800
y-16	-5300	-3280	0	-8150	-16730	- 5300
y-18	-2600	-1600	0	-4050	- 8250	- 2600
1-2	-1800	0	-2500	0	- 4300	- 1800
2-3	+2400	-8200	+12600	0	+15000	- 5800
3-4	-2700	+3200	- 7150	0	- 9850	+ 500
4-5	+3050	-3680	+ 8250	0	+11350	- 630
5-6	-3600	+2150	- 7200	0	-10800	- 1450
6-7	+4000	-2320	+ 7800	0	+11800	+ 1680
7-8	-4500	+1600	- 7850	0	-12350	- 2900
8-9	+4800	-1700	+ 8300	0	+13100	+ 3100
9-10	0	0	0	0	0	0
10-11	-11400	+ 100	- 8000	-4950	-24350	-11300
11-12	+10750	- 100	+ 7600	+4700	+23050	+10650
12-13	-13000	+ 660	- 5880	-10650	-29530	-12340
13-14	+12300	- 600	+ 5550	+10100	+27950	+11700
14-15	-25000	-3200	- 3260	-25200	-53460	-25000
15-16	- 6800	-4140	0	-10150	-21090	- 6800
16-17	+ 4700	+2830	0	+ 7150	+14780	+ 4700
17-18	- 4500	-2750	0	-6800	-14050	- 4500
x-a		+3400	-13230		-13230	+ 3400
y-a		-3050	+ 3940		+3940	- 3050

TABLE 2.

Stresses Truss "3".

Member	Dead Load	Wind Right	Wind Left	Live Load	Maximum	Minimum
x-10	- 3800	-2300	-4330	- 6660	-12580	- 3800
x-11	- 450	- 970		- 800	- 2220	- 450
x-13	+ 800	-1450		+ 1050	+ 1850	- 650
x-15	+ 6200	+ 180		+ 9060	+15880	+ 6200
x-17	+ 3100	- 300		+ 4350	+ 7450	+ 2800
x-18	+ 3100	+1150		+ 4500	+ 8750	+ 3100
y-10	0	-4920		0	- 4900	0
y-12	- 450	-3950		- 800	- 5200	- 450
y-14	+ 600	-3070		+ 900	- 3070	+ 600
y-16	- 5400	-3280		- 7850	-16530	- 5400
y-18	- 2700	-1600		- 3900	- 8200	- 2700
10-11	+ 1600	+2960		+ 2400	+ 6960	+ 1600
11-12	- 1550	-2800		- 2250	- 6600	- 1550
12-13	- 3500	+2750		- 5850	- 9350	- 750
13-14	+ 3300	-2570		+ 5000	+ 8300	+ 730
14-15	-11600	- 300		-17400	-29300	-11600
15-16	- 6750	-4150		-10300	-21200	- 6750
16-17	+ 4700	+2900		+ 7200	+14800	+ 4700
17-18	- 4500	-2800		- 6900	-14200	- 4500

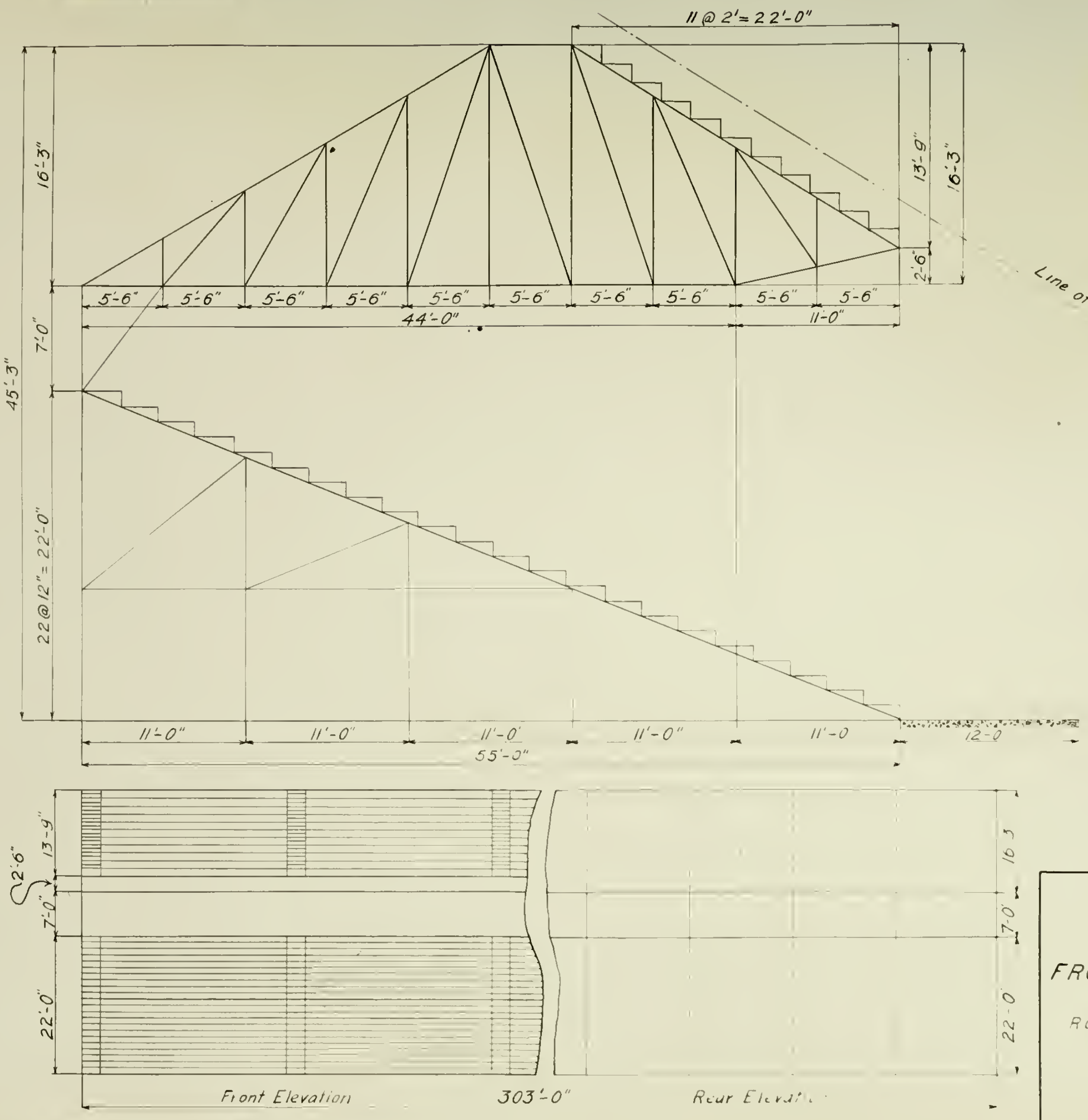

PLATE I
TRANSVERSE SECTION
FRONT and REAR ELEVATIONS

Thesis 19 3

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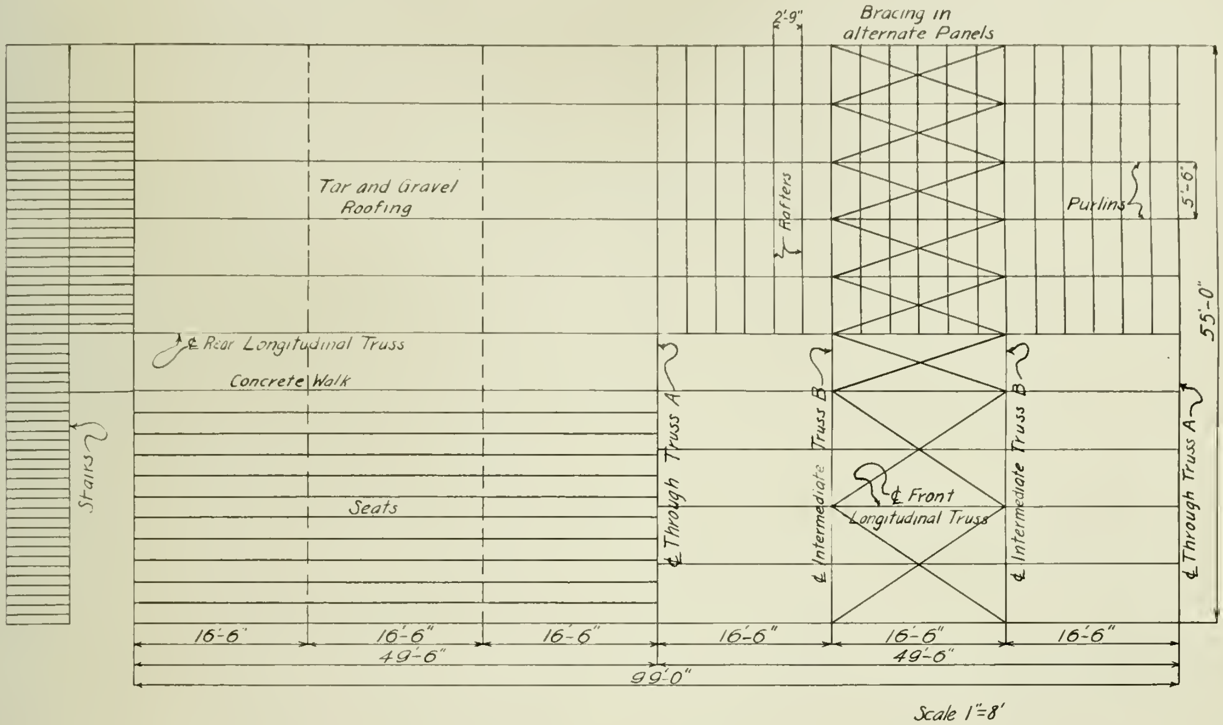
Scale



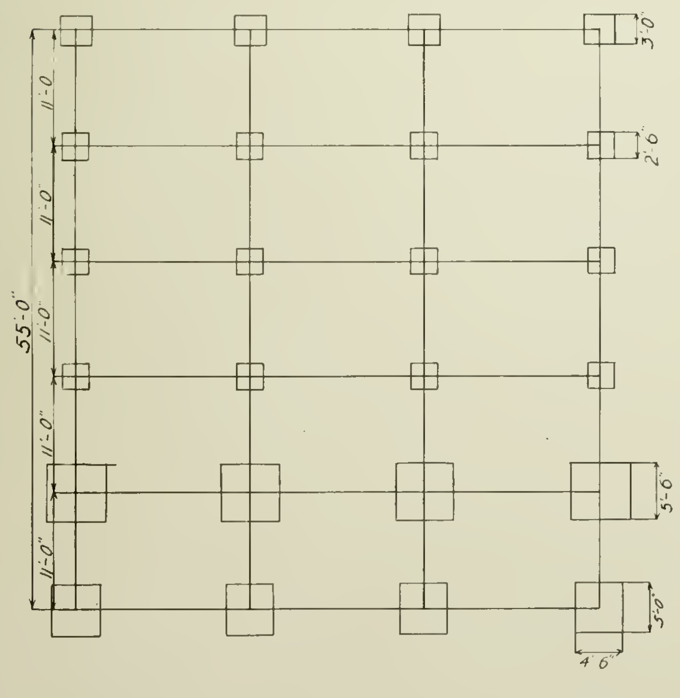


PLATE II

PLAN OF

UPPER and LOWER DECKS

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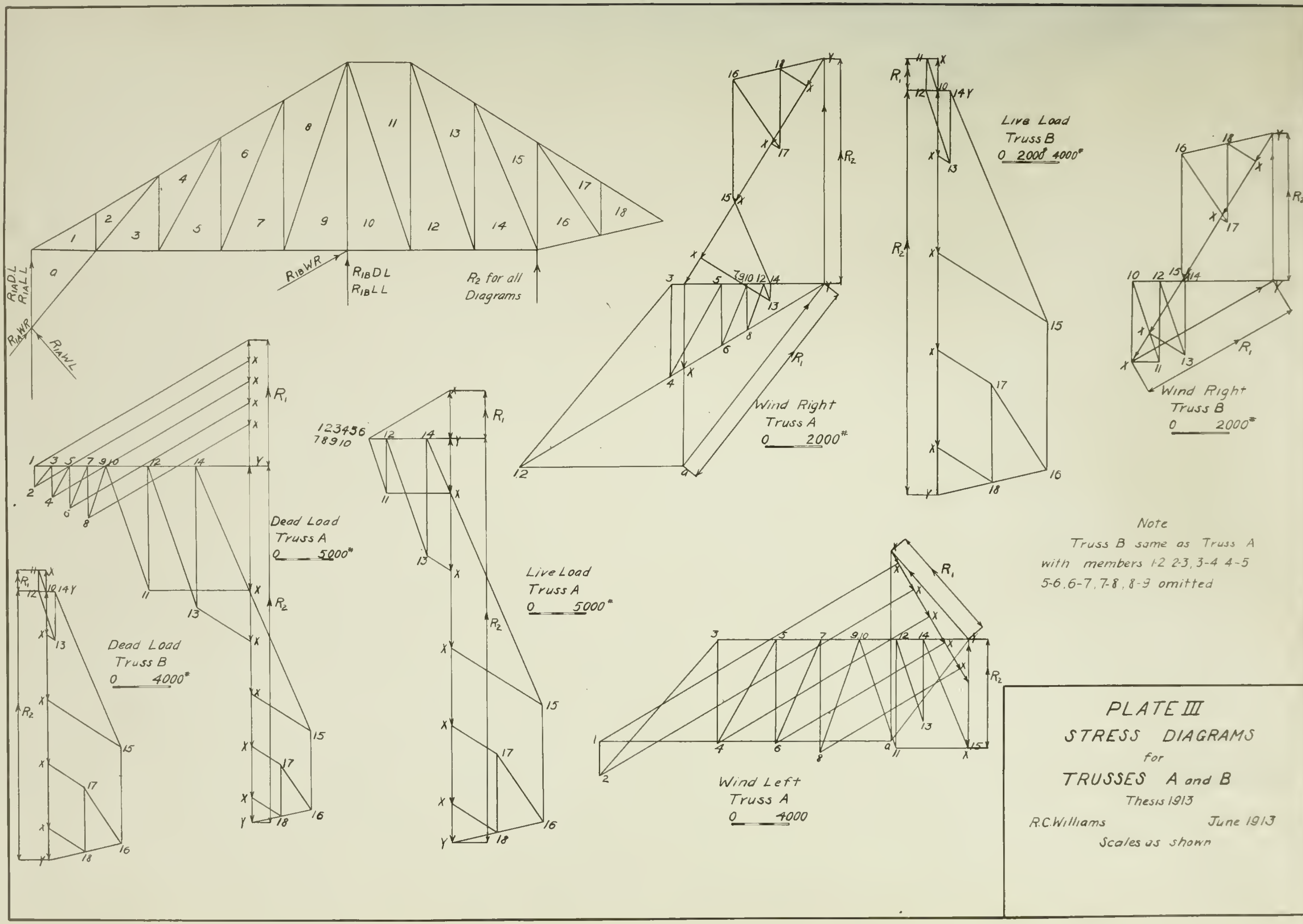

PLATE III
STRESS DIAGRAMS
for
TRUSSES A and B
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Scales as shown

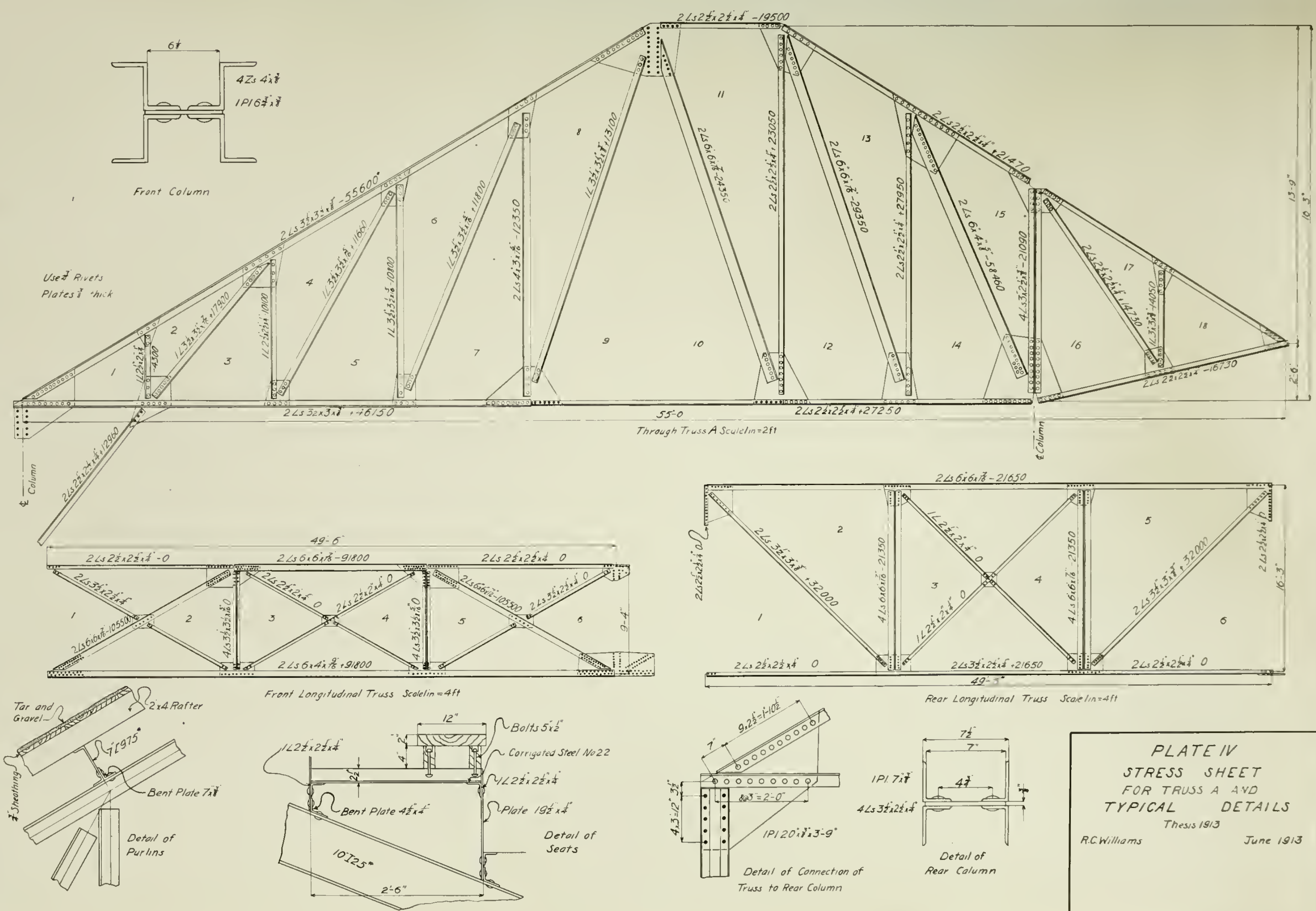

PLATE IV

STRESS SHEET
FOR TRUSS A AND
TYPICAL DETAILS

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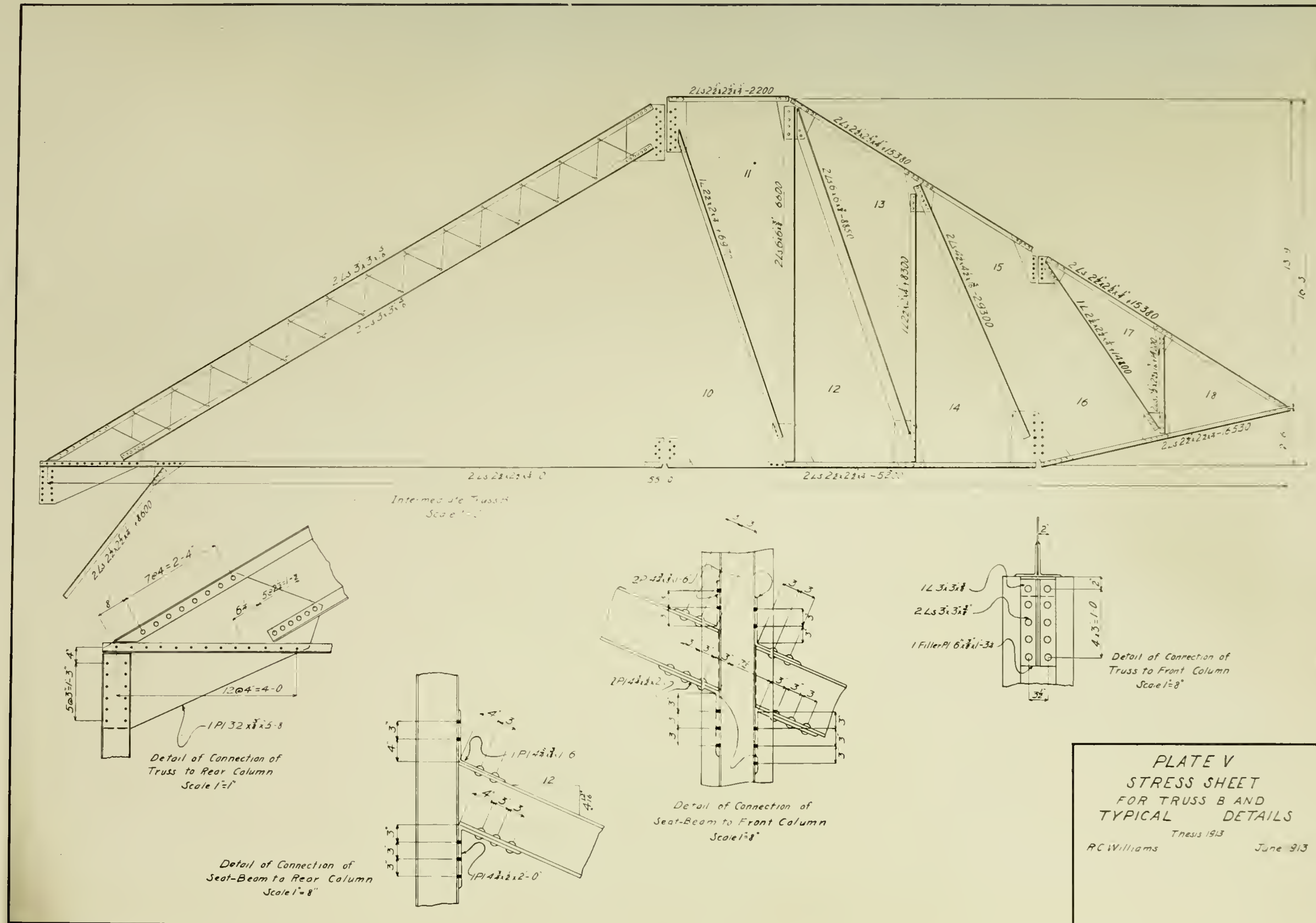

PLATE V
STRESS SHEET
FOR TRUSS B AND
TYPICAL DETAILS
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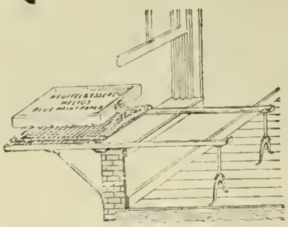
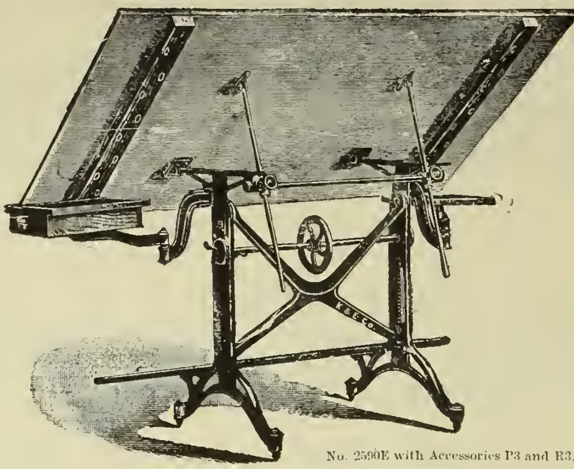
DRAWING K&E TOOLS

ARE FOUND IN EVERY MODERN ENGINEERING OFFICE





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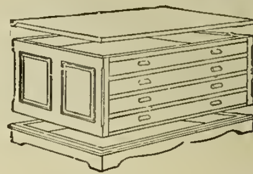

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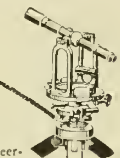

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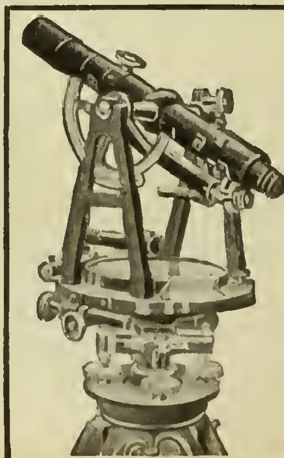

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